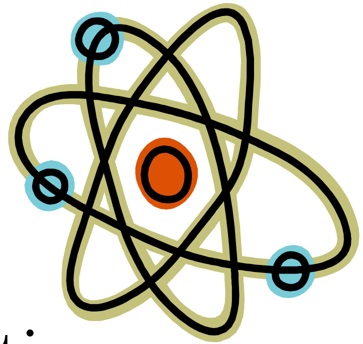
Introduction to Nuclear Chemistry

Types of Radioactive Decay & Nuclear Stability

BASIC TERMS



- Nuclear chemistry—study of nuclear reactions and their uses
- Review of basic terms:
  - Nucleon—particles in the nucleus (proton (p^+) and neutron (n^0))
  - Mass number—the total number of nucleon
  - Atomic number—the number of protons
    - # of neutrons = mass # - atomic #
  - Isotope—same number of protons but different amount of neutron

Mass number → $^{238}_{92}U$ ← Atomic number

Radioactivity & Nuclear Equations

- Most nuclei are stable
- When they are not stable the nuclei is known as a radionuclide
  - Radioisotopes—atoms containing radionuclide
  - Spontaneously emit particles and/or electromagnetic radiation
    - Called radioactive decay
- Nuclear Equations
  - Describe the radioactive decay
  - Total number of nucleons and total number of protons remain the same throughout
    - Are equal on both sides of the reaction

$$^{238}_{92}U \rightarrow {}^{234}_{90}Th + {}^{4}_{2}He$$

Types of Radioactive decay

- Alpha (α)-particle production
  - Releases an alpha particle, which is a helium nuclide ($^{4}_{2}He$)
  - Occurs in heavy radioactive nuclides
  - Example:
    - $^{230}_{90}Th \rightarrow {}^{4}_{2}He + {}^{226}_{88}Ra$
- Beta (ß)-particle production
  - Release of an electron ($^{0}_{-1}e$)
  - Example:
    - $^{131}_{53}I \rightarrow {}^{0}_{-1}e + {}^{131}_{54}Xe$

Types of Radioactive Decay

- Gamma (γ)-ray production
  - Produces a high-energy photo $\left({}_{0}^{0}\gamma\right)$
- Positron production
  - Emits a position $\left({}_{1}^{0}e\right)$, which is a particle with the same mass as a electron but opposite charge
  - Example:
    - ${}_{83}^{205}Bi \rightarrow {}_{1}^{0}e + {}_{82}^{205}Pb$
- Electron capture
  - Nucleus captures an inner orbital electron
  - Example:
    - ${}_{96}^{241}Cm + {}_{-1}^{0}e \rightarrow {}_{95}^{241}Am$

Radioactive Decay Summary

TABLE 21.2 Common Particles in Radioactive Decay and Nuclear Transformations

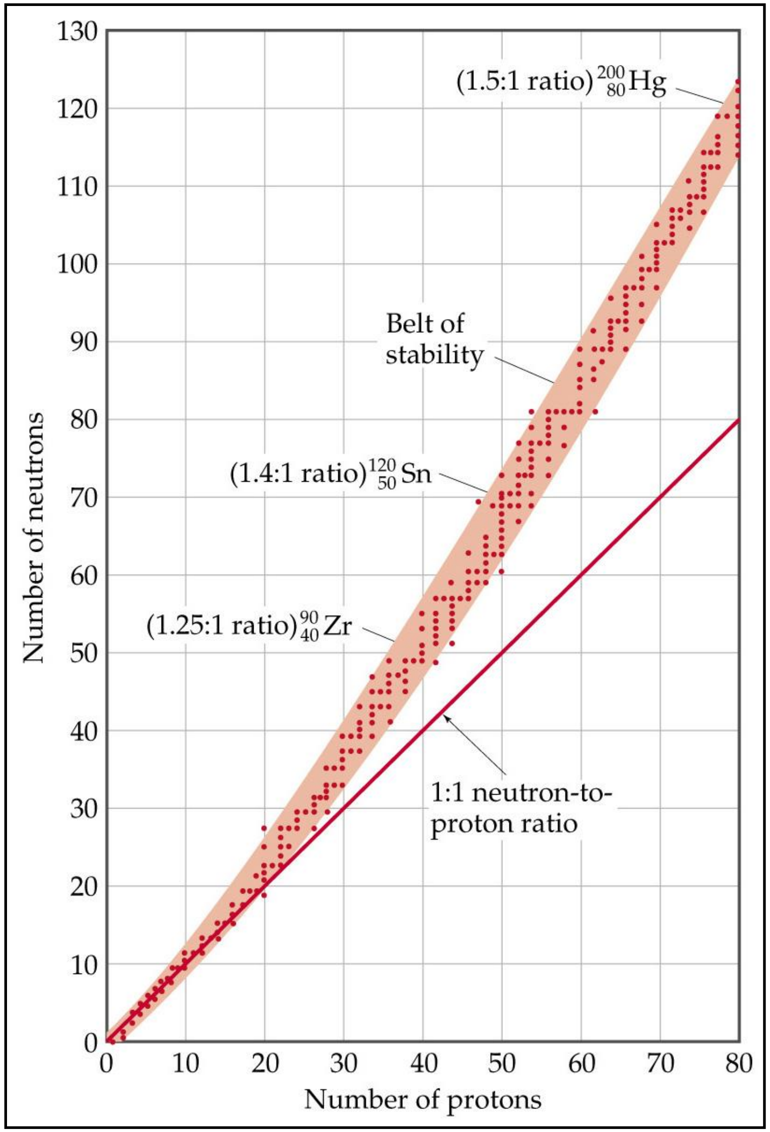
Particle	Symbol
Neutron	${}^{1}_{0}n$
Proton	${}^{1}_{1}H$ or ${}^{1}_{1}p$
Electron	${}^{0}_{-1}e$
Alpha particle	${}^{4}_{2}He$ or ${}^{4}_{2}\alpha$
Beta particle	${}^{0}_{-1}e$ or ${}^{0}_{-1}\beta$
Positron	${}^{0}_{1}e$

Nuclear Stability

- Strong nuclear force—the attractive force between neutrons and protons
  - Proton has high mass and high charge so 2 protons close together causes a large repulsion
  - Stronger than repulsion between 2 protons

- Addition of more protons = more repulsion
  - Need more neutrons for stability

Belt of Stability



- Belt of stability—region in which nucleus is stable
  - For lighter elements, 1:1 proton: neutron ratio works for stability
  - For heavier elements, more neutrons are needed to maintain stability
    - Deviates from 1:1 proton: neutron ratio
  - All elements are 83 (Bismuth) are radioactive and unstable

General Rules about Nuclear Stability

- Certain number of protons and neutrons are inherently stable ("magic numbers")
  - 2, 8, 20, 28, 50, & 82 for protons
  - 2, 8, 20, 28, 50, 82, & 126 for neutrons

- Nuclei with even number of protons and neutrons are much more stable than nuclei with odd number of protons and neutrons

Radioactive Decay & Nuclear Stability

- Nuclei above the belt of stability undergo beta-production
  - An electron is lost and the number of neutrons decreases, the number of protons increases
- Nuclei below the belt of stability undergo positron emission or electron capture
  - This results in the number of neutrons increasing and the number of protons increasing
- Nuclei with atomic numbers greater than 83 usually undergo alpha-production
  - The number of protons and neutrons decrease in steps of 2